CANTILEVER TRACKING TYPE SCANNING PROBE MICROSCOPE

BACKGROUND OF THE INVENTION

The present invention relates to a scanning probe microscope for measuring surface information on a sample with an atomic-order resolution for example.

Conventionally, a scanning tunneling microscope (STM) has been contrived as an example of a scanning probe microscope (SPM) by Binnig, Rohrer, et al. However, the STM can be used to observe electrically conductive samples only. Accordingly, there has been proposed an atomic force microscope (AFM, see Jpn. Pat. Appln. KOKAI Publication No. 62-130302) as an apparatus that utilizes the element techniques of the STM, including the servo technique, for the observation of insulating samples with an atomic-order resolution.

The AFM, which is regarded as an example of the SPM, comprises a cantilever **4**, a scanner (e.g., a tube-type piezoelectric-scanner) **8**, and a displacement sensor **10**, as shown in FIG. **9**, for example. The cantilever **4** has a pointed probe **2** on its free end. The scanner **8** supports the cantilever **4** and causes the probe **2** and a sample **6** to move relatively to each other. The displacement sensor **10** can, for example, optically detect deflection of the free end of the cantilever **4**.

The cantilever **4**, having its proximal end portion supported on a mount **12**, is removably attached to a moving end of the scanner **8**. The scanner **8** has its proximal end portion mounted on a specific base **14**. The displacement sensor **10** contains therein an optical system, such as a laser oscillator or photosensor, and is attached to the moving end of the scanner **8** (first prior art).

When the probe **2** is brought close to the sample **6** placed on a stage **16**, in this arrangement of the first prior art, the free end of the cantilever **4** is displaced by interactions (e.g., atomic force, contact force, viscosity, frictional force, magnetic force, etc.) between the tip of the probe **2** and the surface of the sample **6**. Surface information (e.g., irregularity information) on the sample **6** or the like is measured three-dimensionally by relatively scanning the sample surface in the X- and Y-directions with the probe **2** while optically detecting the displacement of the free end (or feedback-controlling the scanner **8** in the Z-direction to keep the displacement of the free end constant).

Scanning probe microscopes having a scanner with improved scanning response are described in U.S. Pat. Nos. 5,463,897 and 5,560,244, for example.

Each of these scanning probe microscopes comprises a laser oscillator **18**, a lens **20**, and a photosensor (e.g., four-division photodiode) **22**, as shown in FIG. **10**A, for example. The laser oscillator **18** can deliver a specific laser beam into the scanner **8** through an aperture **14***a* that is formed in the base **14**. The lens **20** can converge the incident laser beam, delivered from the oscillator **18** into the scanner **8**, on the cantilever **4** (more specifically, on the back surface of the cantilever **4** opposite from that surface to which the probe **2** is attached). The photosensor **22** can receive reflected light from the back surface of the cantilever **4** when the laser beam is converged thereon.

The lens **20** is positioned and fixed to a mounting frame **24** in the scanner **8** so that the laser beam from the laser oscillator can be incident on the center of the lens **20**. The photosensor **22** is supported on a support member **26** that is attached to the base **14**. It can be moved parallel to its light receiving surface **22***a* (second prior art).

For other constructions, the second prior art resembles the first one. In the description to follow, therefore, like reference numerals are used to designate like portions, and a description of those portions is omitted.

In this arrangement of the second prior art, the laser beam emitted from the laser oscillator **18** is converged on the back surface of the cantilever **4** by the lens **20** after it is applied to the lens **20** through the aperture **14***a* in the base **14**.

As this is done, the reflected light from the back surface of the cantilever **4** is applied to the photosensor (e.g., four-division photodiode) **22**, and is converted into specific electrical signals (more specifically, electrical signals with intensities corresponding to the quantities of received light and/or the positions of light reception).

If the moving end of the scanner **8** is moved in the X- or Y-direction (e.g., in the X-direction) in this state, the cantilever **4** moves for substantially the same distance in the X-direction as the movement of the moving end. The attachment position of the lens **20** is adjusted in consideration of the focal distance so that the laser beam can be converged on the back surface of the cantilever **4** during X- and Y-direction scanning.

According to the first prior art, however, the cantilever **4**, displacement sensor **10**, and mount **12** are attached to the moving end of the scanner **8**. Accordingly, the mass that acts on the moving end of the scanner **8** increases, so that the kinetic mass of the moving end increases. Thus, the resonance frequency of the scanner **8** is lowered, so that the scanning response for the X-, Y-, and Z-directions is lowered inevitably.

In measuring surface information on the sample **6** (e.g., semiconductor circuit pattern) that has a sharp stepped portion **6***a*, such as the one shown in FIG. **10**B, for example, by means of the scanner **8** with low scanning response (or having a moving end with substantial kinetic mass), the displacement motion of the scanner **8** in the Z-direction cannot catch up with the scanning operation if the scanning speed for the X- and Y-directions is increased. Thus, it is difficult accurately to measure the surface information on the sample **6**.

Further, the displacement sensor **10** is fitted with an adjusting knob for adjusting the relative positions of the aforesaid optical system and the cantilever **4**, and the scanner **8** is subjected to a bending moment by means of an operating force that is applied to the displacement sensor **10** as the knob is manipulated. In general, the scanner **8** is formed of a thin ceramic material and is bonded to the base **14** with a specific adhesive agent. If the scanner **8** is subjected to the bending moment, therefore, it may be damaged or separated from the base **14**, in some cases.

Although the second prior art is an improved technique that has been developed to solve the aforesaid problem of the first prior art, it is based on the sacrifice of some other technical effects of the first prior art.

Now let it be supposed that the moving end of the scanner **8** is displaced without any interaction between the sample **6** and the probe **2** (i.e., with the cantilever **4** kept distant enough from the sample **6**).

According to the first prior art, the relative positions of the optical system of the displacement sensor **10** and the cantilever **4** are kept fixed without being influenced by the state of displacement of the moving end of the scanner **8**, so that the position and angle of incidence of the laser beam on the cantilever **4** never change. In consequence, the position of application of the reflected light from the cantilever **4** to the photosensor **22** can be also kept constant. Thus, the electrical